DEPARTMENT OF
ECOLOGY
State of Washington

Quality Assurance Project Plan

Performance Evaluation of Devices for Stormwater Particulate Sampling

October 2011

Publication No. 11-03-113

Publication Information

Each study conducted by the Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

This plan is available on Ecology's website at www.ecy.wa.gov/biblio/1103113.html.

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, DOST0001.

Ecology's Activity Tracker Code for this study is 11-061.

Waterbody Numbers:

- Thea Foss Waterway WA-10-0020
- Spokane River WA-57-1010

Author and Contact Information

David Osterberg and Brandi Lubliner
P.O. Box 47600
Environmental Assessment Program
Washington State Department of Ecology
Olympia, WA 98504-7710

For more information contact: Communications Consultant, phone 360-407-6834.

Washington State Department of Ecology - www.ecy.wa.gov/

○ Headquarters, Olympia	360-407-6000
○ Northwest Regional Office, Bellevue	425-649-7000
○ Southwest Regional Office, Olympia	360-407-6300
○ Central Regional Office, Yakima	509-575-2490
○ Eastern Regional Office, Spokane	509-329-3400

Any use of product or firm names in this publication is for descriptive purposes only and does not imply endorsement by the author or the Department of Ecology.

If you need this document in a format for the visually impaired, call 360-407-6834.
Persons with hearing loss can call 711 for Washington Relay Service.
Persons with a speech disability can call 877-833-6341.

Quality Assurance Project Plan

Performance Evaluation of Devices for Stormwater Particulate Sampling

October 2011

Approved by:

Signature:	Date: October 2011
Ted Hamlin, Client, Water Quality Program, ERO	
Signature:	Date: October 2011
David Moore, Acting Unit Supervisor, Water Quality Program, ERO	
Signature	Date: September 2011
James Bellatty, Client's Section Manager, Water Quality Program, ERO	
Signature:	Date: September 2011
Brandi Lubliner, Co-Author / Project Manager, TSU, EAP	
Signature:	Date: October 2011
David Osterberg, Author / EIM Data Engineer, TSU, EAP	
Signature:	Date: September 2011
Dale Norton, Author's Unit Supervisor, TSU, EAP	
Signature:	Date: September 2011
Will Kendra, Author's Section Manager, EAP	
Signature:	Date: October 2011
Stuart Magoon, Director, Manchester Environmental Laboratory, EAP	
Signature:	Date: September 2011
Bill Kammin, Ecology Quality Assurance Officer	

Signatures are not available on the Internet version.

ERO: Eastern Regional Office.
TSU: Toxics Studies Unit.
EAP: Environmental Assessment Program.
EIM: Environmental Information Management database.

Table of Contents

Page

List of Figures and Tables....................3

Abstract....................4

Background....................5
- Existing Methods for Sampling Stormwater Particulates....................5
- Design Criteria for a New Particulate Sampler....................8

Project Description....................12
- Prototype Testing....................12
- Methods Comparison....................12

Organization and Schedule....................14
- Personnel Organization....................14
- Project Schedule....................15

Study Design....................16
- Site Selection....................16
- Timing of Sample Collection....................16
- Target Analyses....................18

Sampling Procedures....................20
- Sediment Collection Methods....................21
- Particulate Size Analysis Using the LISST Instrument....................23

Laboratory Measurement Procedures....................25

Quality Objectives....................26

Quality Control Procedures....................27
- Field....................27
- Laboratory....................28

Laboratory Cost Estimate....................29

Data Management Procedures....................30

Data Verification....................30

Data Quality (Usability) Assessment....................31

Audits and Reports....................31

References....................32

Appendices....................34
- Appendix A. PAH Compounds and PCB Congeners....................35
- Appendix B. Glossary, Acronyms, and Abbreviations....................35

List of Figures and Tables

Page

Figures

Figure 1. Modified Ecology Stormwater Sediment Bottle Trap. 7

Figure 2. Early Design Flow-Over Stormwater Sediment Traps Designed by City of Vancouver, BC and City of Tacoma, WA (courtesy City of Tacoma). 8

Figure 3. Hamlin Prototype Stormwater Particulate Sampler. 9

Figure 4. The Interior of the Prototype Sampler. 10

Figure 5. Example Deployment Configuration of the Hamlin Sampler. 11

Tables

Table 1. Organization of Project Staff and Responsibilities. 14

Table 2. Proposed Schedule for Completing Field and Laboratory Work, Data Entry into EIM, and Reports. 15

Table 3. Physical and Chemical Analyses for the Project. 19

Table 4. Sample Containers, Preservations, Holding Times, and Minimum Sample Sizes. 20

Table 5. Laboratory Reporting Limits and Analytical Methods. 25

Table 6. Measurement Quality Objectives for Laboratory Analyses. 26

Table 7. Anticipated Analyses of Field Duplicate Samples for Quality Assurance. 27

Table 8. Laboratory Quality Control Samples. 28

Table 9. Cost of Sample Analyses. 29

Abstract

During 2009 and 2010 the Washington State Department of Ecology (Ecology) Eastern Regional Office developed an in-line sampling device for the passive collection of stormwater particulates for contaminant analysis. Initial trials with a prototype model demonstrated rapid particulate capture, indicating that it may allow for short-duration sampling of storm events.

We will conduct a study to further evaluate the performance of the prototype sampler under actual field conditions. Test locations will include two sites in the City of Tacoma, Washington stormwater system and one site in the City of Spokane, Washington. Sampling will occur from August through December of 2011, targeting three storm events at each site. Performance metrics will include mass of particulates collected by size class and duration required to collect sufficient material for typical chemical analyses.

Concurrently, we will conduct a methods comparison on two sampling occasions at one site, to compare the prototype device to four other existing techniques for stormwater particulate collection. In addition, we will use a laser diffraction instrument to measure the size distribution of in-situ stormwater particulates. We will collect particulates by the various techniques and analyze for important particulate-associated contaminants such as metals and non-polar organic compounds. Comparisons of the mass, size distribution, and chemistry of the captured particulates will help clarify the relative merits of each sampling method.

Results from this project will help determine the appropriate uses and limitations of the new prototype sampler and will provide a valuable comparison between other existing stormwater sediment sampling techniques.

Background

Particulates carried by stormwater are believed to be a major transport mechanism for contaminants (such as metals and organic compounds) that can potentially impair receiving water quality and degrade ecosystem health. Mobilization and transport of particulates via stormwater discharges is therefore of fundamental interest to groups concerned with reducing overall contaminant loadings to receiving waters.

In recent years, monitoring activities in support of stormwater quality regulation and control have increasingly focused on particulates in stormwater discharges. These efforts included:

- **Source identification monitoring** to detect and characterize sources of pollution. By determining the specific locations of contaminant sources within a drainage system, remediation efforts can be prioritized and effectively targeted to reduce downstream impacts.
- **Status and trends monitoring** to track the impacts of management actions on stormwater quality through time.
- **Efficacy monitoring** to evaluate how well best management practices (BMPs) work to reduce the impacts of stormwater on receiving waters.

Although monitoring particulates is becoming a presumptive component of stormwater management strategies, multiple methods for sampling particulates currently exist. Different programs monitoring the same characteristics, e.g., particulate-associated contaminant concentrations and solids removal efficiency, often use different sampling equipment, generating data that may not be comparable between studies. These inconsistencies inhibit the interpretation and use of results for stormwater management.

Existing Methods for Sampling Stormwater Particulates

Conventional sediment sampling techniques target either particulates moving within stormwater conveyance systems or those deposited at the discharge point. These commonly used techniques to capture sediment or particulate samples are:

- **Sediment grabs.** With a scoop attached to a pole, a Ponar grab sampler, or an Ekman grab sampler, sediments are collected from a structure, e.g., catch basin, junction box, or BMP, or from the environment near the pipe outfall in the receiving waters.
- **Whole water sampling.** A grab or composite stormwater sample is collected from a conduit or other structure using manual or automatic equipment. Whole water samples are analyzed for total and dissolved contaminants. The particulate-bound fraction is calculated as the difference between the whole and filtered water concentrations.
- **Filtration.** Stormwater is pumped from a conduit or other structure and forced through a filter medium. Solids are extracted in the lab for contaminant analysis.

- **Continuous-flow centrifugation.** Stormwater is pumped from a conduit or other structure, and particulates are separated with centrifugal force by continuously spinning the diverted flow sample.
- **Sediment traps.**
  - ***Bottle traps*** **–** A bottle trap is an open sample bottle mounted vertically or at a slight angle into the flow in a conduit or other structure, where particulates are collected by passive accumulation within the bottle. Particulates settle out of the water inside the bottle, and continual fluid exchange introduces particulate-laden stormwater from outside the trap while removing particulate-deficient water from inside.
  - ***Flow-over traps*** **–** Water in the pipe system is allowed to flow over a low-profile box mounted directly to the bottom of the stormwater system with screening as the lid. As in the bottle trap method, water and entrained particles enter the trap and settle out in the more quiescent setting below the screening material. The sediments collect in a tray at the bottom of the trap. The trap itself is placed along the bottom of the pipe system to passively sample the water column and entrained sediments.

Bottle Traps

A review by Barnard and Wilson (1995) found that, with the exception of sediment traps, these existing particulate sampling methods are generally expensive, labor-intensive, high-maintenance, and difficult to coordinate with runoff conditions. In contrast, sediment bottle traps developed by Ecology are a simple, low-cost, low-maintenance option that has proven effective in a variety of stormwater conveyance structures (Wilson and Norton, 1996; Norton, 1997). After initial trap installation, deployments and retrievals require minimal effort. Particulate collection proceeds passively over a period of months, and the trapped solids represent a time-integrated sample, often from multiple storm events. The quantity of particulates captured usually ranges from 50 to several hundred dry grams (Wilson and Norton, 1996; Norton, 1997 and 1998) for contaminant analyses.

For these reasons, the Ecology-designed stormwater sediment bottle traps have emerged as the most commonly employed sampling method for stormwater particulates. Figure 1 shows an example of the bottle trap design which the City of Tacoma modified by adding a collar over the bottle and adjustable arms. The original design was modified further and now the traps are often referred to as the “modified Ecology stormwater sediment bottle trap” or “modified Norton stormwater sediment bottle trap.”

Despite their advantages, sediment bottle traps have several drawbacks:

- The great length of time required to collect sufficient mass of particulates, which typically ranges from one to six months.
- The lack of information on the fraction of particulates that are sampled and whether the collected solids are representative of stormwater particle sizes.
- The inability to deploy bottle trap installations in some stormwater conveyance systems where anchoring is not feasible or allowed.

Figure 1. Modified Ecology Stormwater Sediment Bottle Trap.
(Courtesy City of Tacoma)

The bottle trap sampler produces information about long-term stormwater quality. However, many monitoring situations benefit from sampling methods which can characterize particulate-associated contaminants from a single storm event, i.e., on the order of days or several weeks.

Overall, existing sampling techniques for collecting stormwater particulates are unsuitable or inadequate for many monitoring needs. There is thus a growing interest in the development of new methods and equipment, designed specifically for stormwater applications, which can capture the full range of physical and chemical characteristics of the transported particulates.

Flow-Over Traps

In 2007, research scientists from the City of Tacoma, Washington, and the City of Vancouver, British Columbia, developed a stormwater sediment trap to mount within a pipe and collect a larger mass of material for sampling. These flow-over traps have been used and modified by both cities with some success. Sampling timeframes shrink from 1 year to 3 months in several Tacoma stormwater systems. (Rick Fuller, personal communication, 2011). Figure 2 shows the first iterations of these flow-over traps.

Around this same time, Ecology's Urban Waters Program, while identifying, tracking, and eliminating sources of pollution to the Spokane River, needed to sample stormwater sediment without anchoring to the stormwater pipe network. Unaware of the efforts in Vancouver and Tacoma, Ecology began brainstorming for a new device in Spokane.

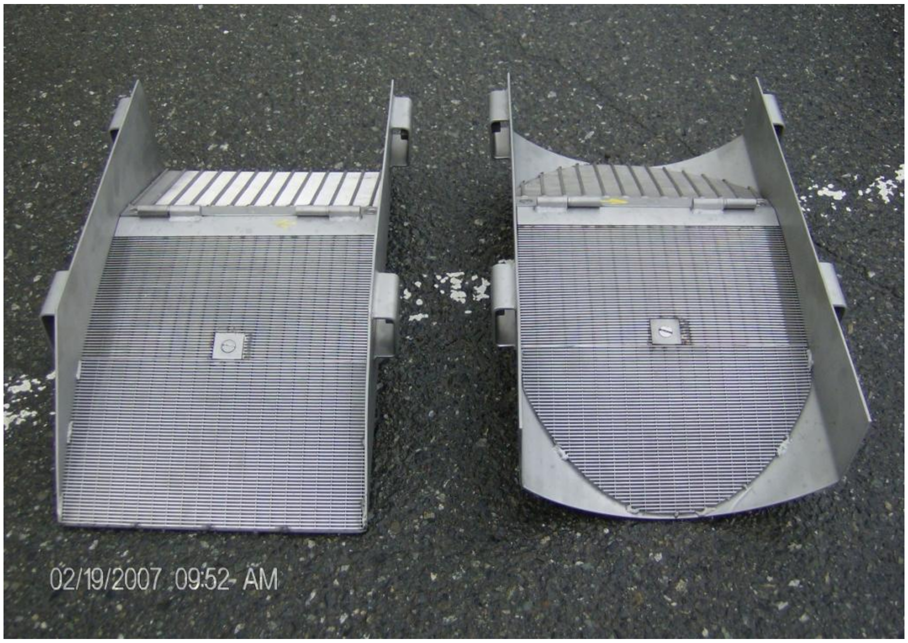

Figure 2. Early Design Flow-Over Stormwater Sediment Traps Designed by City of Vancouver, BC and City of Tacoma, WA (courtesy City of Tacoma).

Design Criteria for a New Particulate Sampler

For stormwater monitoring, a particulate sampler needs to:

- Passively collect representative stormwater particulates from a high-energy, storm-drain environment.
- Not require bolt anchoring.
- Collect material over a wide range of particulate sizes.
- Collect material in sufficient mass to perform a variety of chemical analyses.
- Collect a sufficient amount of material within a relatively short sampling period, i.e., days to weeks.
- Operate for the duration of one or more storm events without maintenance.
- Be constructed of non-contaminating materials.
- Resist fouling and/or damage by debris.
- Be adaptable to a variety of drainage structures.
- Be easily deployed, retrieved, and transported.
- Be relatively inexpensive to manufacture and maintain.

A device meeting all of these criteria would offer improvements over existing sampling equipment. A short sampling duration would allow targeting a single storm or first-flush event (versus the several months that sediment bottle traps require to collect adequate material). Collecting a larger mass of particulates, if available, could allow for a larger suite of chemical analyses and lower detection limits.

A Prototype Low-Profile Sampling Device

Ecology's Urban Waters Program led the effort to develop a device to capture ample particulates carried in stormwater for analysis. The existing sampling techniques were not suitable for application in the Spokane watershed, motivating us to develop an alternative technology. In particular we needed to develop a sediment collection device that did not require bolts to anchor to the stormwater pipes. Our Spokane office began testing early iterations of a novel sampling device for collecting stormwater particulates in 2009.

This sampling device, called the Hamlin Prototype, (Figure 3) is designed for in-line sampling in stormwater conduits with uni-directional flow. When deployed, the sampler lies flush with the bottom of a pipe facing into the flow. The leading edge of the sampler consists of a tongue piece that extends at an angle downward to meet the bed of the pipe. As stormwater moves through the pipe, this tongue piece functions as a ramp, directing the flow up and over the sampler. The rear edge of the sampler has a lip perpendicular to the direction of flow that functions as an obstruction to the stormwater flowing over the top of the sampler. This obstruction creates an area of decreased velocity directly over the sampler intakes, to encourage the settling of particulates. The top of the sampler has three slits (parallel to the direction of flow; each ¼-inch wide) through which particulate-laden stormwater enters.

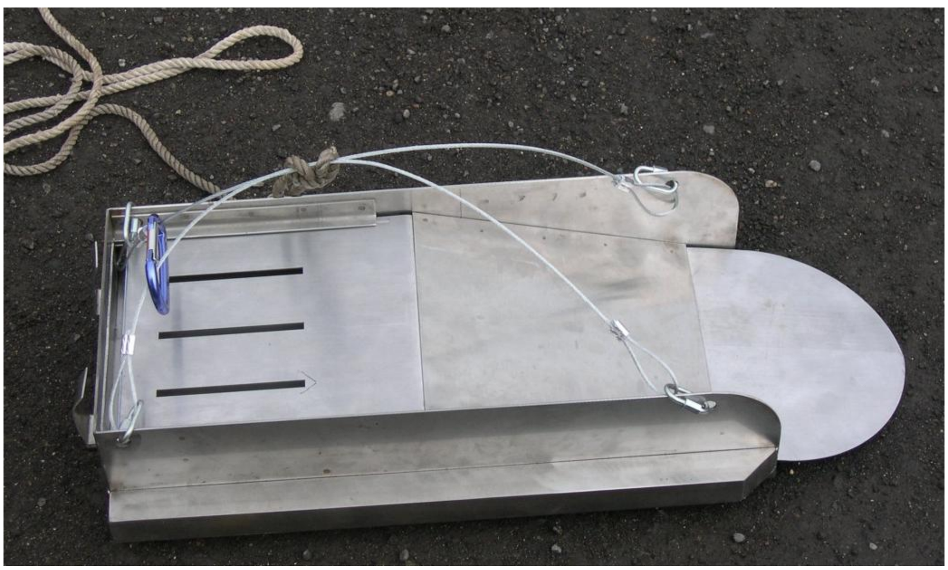

Figure 3. Hamlin Prototype Stormwater Particulate Sampler.

The interior of the sampler (Figure 4) consists of two levels designed to maximize the residence time. Increased residence time allows stormwater particulates to settle out (Gardner, 1980a and 1980b). Upon entering the sampler's upper chamber, the stormwater flows forward and falls through three additional slits (each ¼-inch wide) into the lower level and reverses flow direction yet again. In the lower chamber, the stormwater encounters a series of six baffles – vertical barriers affixed to the bottom of the sampler – that further slow the flow and create pockets of low turbulence where particulates can settle and not be easily re-suspended. Small ports at the rear of the lower chamber allow stormwater to exit the sampler.

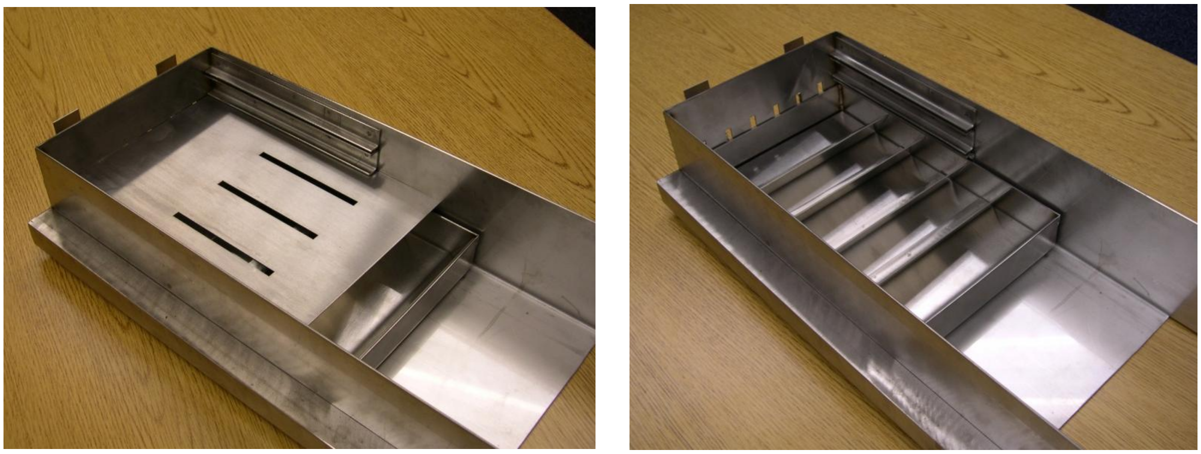

Figure 4. Interior of the Hamlin Prototype Sampler.

Upper Chamber (left) and Lower Chamber (right, with Baffles and Exit Ports)

Designed specifically for the high-energy environment of stormwater conveyance systems, the new sampler is constructed of all stainless steel (non-contaminating and non-rusting) parts. The dimensions of the sampler are 21.5L x 9.25W x 4H inches; its low profile is intended to resist fouling and accumulating large debris.

The sampler can be installed into stormwater pipes in two ways:

- The first way to deploy does not involve drilling anchors into the pipe walls. Instead, the sampler, at around 20 lbs, is heavy enough to remain at the bottom of the pipe. That position is maintained by securing a rope to the device and to a stationary on-site object, e.g., a ladder rung inside a manhole.
- The second way to deploy is to anchor a stainless steel plate on the front face of a pipe entering a catch basin manhole. The prototype sampler has latches at the back of the device to securely hook onto the steel plate so the sampler faces the oncoming flow. An example of this deployment configuration is shown in Figure 5. As such, the sampling location must have overhead access ($\geq$ 22 inches wide to accommodate the sampler), but deployments and retrievals do not require confined-space entry. Tethering the sampler to the manhole ladder is still advised.

Initial field trials performed using the prototype design indicated that the sampler may offer distinct advantages over the bottle-trap sampler. Particulates were observed to accumulate rapidly, and in several trials ample mass for chemical analyses (approximately 1800 wet grams) was collected in 24 hours (Hamlin, 2010). Grain size analysis of these solids revealed that all size classes of interest were captured, with fine particulates (< 62.5 um) representing up to 55% of the mass of the collected material.

Figure 5. Example Deployment Configuration of the Hamlin Prototype Sampler.

View is from street level, looking down into 22-inch manhole, in Spokane on Union St. Sampler is seated just before the pipe entry and secured to an access ladder rung.

Project Description

Based on the results of the initial field trials, Ecology is conducting a pilot study to further test the prototype design. These investigations will allow better assessment of the appropriate uses and applications of the new sampler for stormwater monitoring purposes. Objectives of the pilot study are to:

- Test the prototype sampler under a variety of actual field conditions.
- Evaluate whether the prototype sampler can collect an adequate mass of particulates for a suite of chemical analyses in a reasonable amount of time.
- Determine the size range of particulates captured by the prototype and by other currently used sampling techniques.
- Compare the capabilities of each sampling technique.

The study design will consist of two principal elements: performance testing of the prototype sampler, and comparing it with other particulate collection methods and sampling equipment or techniques.

Prototype Testing

Performance testing will aim to assess how well the prototype sampler collects particulates in a variety of stormwater monitoring conditions. We will deploy the device at three sites with different drainage basin characteristics such as land use types, and variable structural features such as pipe diameters and gradients. We will install samplers in late August and will sample in September and December of 2011, targeting three storm events at each site. If possible, the first of the three sampling events will target the first flush of particulates and contaminants after the summer dry period.

Metrics for evaluating sampler performance will include *mass* (amount of particulate material collected), *duration* (time required to collect sufficient mass for a typical suite of chemical analyses), *grain size* (mass per size class captured), and *particle size distribution (PSD)* (percent of material in each size class captured).

Methods Comparison

Comparing methods will involve coincident sampling by the prototype device and three commonly used techniques for stormwater particulate collection: sediment bottle traps, centrifugation, bottom sediment grabs. We will sample on two occasions at a single location over the same time interval.

We will analyze particulate samples for:

- Physical parameters: grain size, percent solids, total suspended solids, total organic carbon, suspended sediment concentration, and particle size distribution (in situ).
- Metals: arsenic, cadmium, chromium, copper, lead, zinc, and mercury.
- Organic compounds: PAHs and PCB congeners.

Comparisons between the *mass, grain size, in-situ particle size distribution,* and *chemistry* of the captured particulates will allow evaluation of the capabilities, biases, and relative merits of each method for monitoring applications.

Included in the methods comparison will be an investigation of how well the size distribution of particulates collected by the various sampling techniques represents that of the particulates being transported by stormwater. A laser diffraction instrument will measure the in-situ size distribution of particulates at regular intervals over the course of the storm event. Particulate samples collected by the various sampling techniques at the same time and location will later be analyzed by the laser diffraction instrument and compared with the size distribution measured in the stormwater.

Coincident sampling using a variety of techniques will improve understanding of how the results from different methods relate. Such relationships may facilitate the comparison of results from different sampling methods. Evaluation of the advantages and disadvantages of the various sampling techniques will inform future studies. This investigation will reveal the capabilities and limitations of each sediment collection technique. Stormwater sediment sampling often encounters multiple constraints, requiring a variety of techniques. Understanding the biases or limitations of those techniques benefits both sediment and stormwater studies.

Organization and Schedule

Personnel Organization

Table 1 lists project staff, all employees of the Washington State Department of Ecology.

Table 1. Organization of Project Staff and Responsibilities.

Staff	Title	Responsibilities
Ted Hamlin Water Quality Program Eastern Regional Office Phone: (509) 329-3573	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Conducts sampling activities at Spokane site. Reviews the project report.
James Bellatty Water Quality Program Eastern Regional Office Phone: (509) 329-3534	Section Manager for the Study Area	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Brandi Lubliner TSU, SCS, EAP Phone: (360) 407-7140	Project Manager QAPP Co-Author	Oversees sampling activities and transport of samples to laboratories. Conducts QA review of data, analyzes and interprets data, and writes draft and final reports. Reviews final data in EIM.
David Osterberg TSU, SCS, EAP Phone: (360) 407-6446	QAPP Co-Author	Writes the QAPP. Assists with data analysis and preparation of reports. Enters data into EIM.
Tom Gries TSU, SCS, EAP Phone: (360) 407-6327	Field Assistant	Provides guidance and oversight in use of centrifuge and LISST instruments. Peer reviews draft QAPP.
Dale Norton TSU, SCS, EAP Phone: (360) 407-6765	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Will Kendra SCS, EAP Phone: (360) 407-6698	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Stuart Magoon Manchester Environmental Lab Phone: (360) 871-8801	Director	Approves the final QAPP.
William R. Kammin Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

QAPP: Quality Assurance Project Plan.
TSU: Toxics Studies Unit.
SCS: Statewide Coordination Section.
EAP: Environmental Assessment Program.
EIM: Environmental Information Management database.

Project Schedule

Table 2 shows the proposed schedule for project milestones. These dates may change due to unexpected circumstances. All modifications to the project schedule will be discussed with and approved by the client.

Table 2. Proposed Schedule for Completing Field and Laboratory Work, Data Entry into EIM, and Reports.

Field and laboratory work	Due date	Lead staff
Field work completed	December 2011	Brandi Lubliner
Laboratory analyses completed	February 2012	
Environmental Information System (EIM) database		
EIM user study ID	DOST0001	
Product	Due date	Lead staff
EIM data loaded	June 2012	David Osterberg
EIM quality assurance	June 2012	Brandi Lubliner
EIM complete	July 2012	David Osterberg
Final report		
Author lead / Support staff	Brandi Lubliner/ David Osterberg	
Schedule		
Draft due to supervisor	April 2012	
Draft due to client/peer reviewer	May 2012	
Draft due to external reviewer(s)	Not applicable	
Final (all reviews done) due to publications coordinator	June 2012	
Final report due on web	July 2012	

EIM: Environmental Information Management database.

Study Design

Site Selection

To test the capabilities of the prototype sampler under actual field conditions, three locations will be selected. One of these locations will also be the site of methods comparison sampling. These sampling sites will have the following features:

- Contrasting land use types in their drainage basins, e.g., commercial, industrial, residential.
- Variously sized drainage areas.
- Stormwater conduits of assorted diameters and gradients.
- Uni-directional stormwater flow and above tidal influence.
- Available data from previous stormwater sampling efforts, if possible.
- Existing sediment bottle trap installations, if possible.
- Willingness of the local municipality or owner to allow installation of the various sampling equipment.
- Adequate security for overnight parking of centrifuge trailer.

Based on these requirements, two sites will be selected within the Tacoma stormwater system. In general, locations where previous stormwater particulate sampling has been performed by Ecology or by the City of Tacoma will be given preference. Both Tacoma sites will be used for performance testing of the prototype sampler. To the extent possible these sampling locations will differ in pipe diameters and gradients, as well as in drainage basin characteristics. Methods comparison activities will be conducted at one of the Tacoma sites; therefore, a relatively isolated and secure location with existing sediment bottle trap installations (mounting brackets) will be sought. A catch basin or similar structure, for bottom sediment grabs, will be located immediately downstream of the sampler deployment location at this site.

The third sampling site will be within the Spokane River watershed in the City of Spokane. This location will be used solely for performance testing deployments of the prototype sampler. The drainage basin and pipe (diameter, gradient) characteristics will be distinct from those at the Tacoma sites, allowing comparison of sampler performance over a range of field conditions.

Field reconnaissance will determine final selection of all sampling sites.

Timing of Sample Collection

Prototype Testing

We will performance test the prototype sampler at all three sites from August through December 2011. This sampling will be weather-dependent, targeting three storm events at each location. The trigger to initiate storm-event sampling will be greater than 0.15 inches (3.81 mm) of predicted rainfall with at least 24 hours of antecedent dry weather (< 0.02 inches of rain). We will install the sampler during dry weather before the storm to ensure that particulate collection occurs throughout the rising limb of the hydrograph.

Based on preliminary trials, the duration of sampler deployment is expected to be less than one week, but observed sampler performance will determine actual deployment periods. We will conduct periodic inspections approximately daily during the storm event to check for fouling by debris and to assess the amount of material collected. We will retrieve the sampler when it is at least half full; this may require that the sampler remain in place beyond the end of a storm and into subsequent dry and wet weather periods.

Methods Comparison

Sampling for the methods comparison will be conducted at two Tacoma sites during two storm events that occur from September through December 2011. We will employ five particulate collection techniques (discussed in detail in *Sampling Procedures* section) during the same timeframe:

- Hamlin prototype stormwater particulate sampler.
- Modified Ecology/Norton stormwater sediment bottle trap.
- Fuller stormwater sediment trap.
- Whole water centrifugation.
- Bottom sediment grab.

We plan to determine the duration of sampling by collecting enough material using the centrifuge and by safe re-entry into the stormwater pipes to collect the samples. Centrifugation is expected to require multiple hours, up to 48 hours. Sub-samples from the other samplers (prototype, bottle trap, and bottom sediment grab) will be collected, if enough material exists, after centrifugation.

We expect that the prototype sampler, bottle trap, and bottom sediments may require continued sampling for several days beyond the termination of centrifugation to allow for safe re-entry and collection of sufficient material. These traps will be checked on a regular basis, daily to weekly, to assess mass accumulation. We will collect sediments from deployed traps at the same time, and record sediment mass and duration time. We will note insufficient sediment mass for analyses and will retain and store sediment for a final composite at the end of the study. The maximum amount of time for deployment is three months. After retrieving traps, we will conduct bottom sediment grabs if sufficient material exists.

We will use the laser diffraction instrument in situ, discussed in *Sampling Procedures* section, during methods comparison sampling to measure the particulate size distribution of the stormwater. These measurements will coincide with centrifuge sampling activities, occurring at regular intervals during storm-event sampling.

Target Analyses

We will test the prototype sampler for one storm event before the methods comparison sampling events. Simple physical parameters such as grain size and percent solids will be evaluated during the prototype testing phase of the project from both Tacoma sites and the Spokane site.

During the methods comparison phase, only the two Tacoma sites will be sampled. Both physical and chemical parameters will be evaluated from the methods comparison study. Table 3 summarizes the various sampling methods and analyses that will be performed.

Physical parameters include:

- Grain size
- Percent solids
- Total suspended solids (TSS)
- Total organic carbon (TOC)
- Particle Size Distribution (PSD) using LISST[1]
    - In-situ stormwater reading by LISST
    - Bench analysis using LISST following the Puget Sound Estuary Program protocols (PSEP, 1997)

Grain size analysis will classify the particulates using the Wentworth scale for each sample. The mass of the particulates in each size class, as well as the percent of the total mass represented in each size class, will be reported. Percent solids will be used to convert each sample's wet mass to dry mass measurement. TSS will be measured only to test for percent removal of the sediment by the centrifuge and bag filtration system. Both the inflow and outflow on both sampling occasions will be monitored. TOC results will be used to normalize the organic compound data to reduce the variability associated with differences in TOC content.

The PSD of the solids collected by the various sampling techniques will be analyzed and compared to that of the in-situ stormwater flow, both measured using a laser diffraction instrument. The resulting LISST-PSD data will be like those from standard grain size analysis except the amount of particulates in discrete size classes will be determined on a volumetric basis (uL/L) instead of on a mass basis (ug/g).

Chemical analyses during the methods comparison component of the project will focus on contaminants that have a strong affinity for particulates, including:

- Metals
    - Arsenic
    - Cadmium
    - Chromium
    - Copper
    - Lead
    - Zinc

[1] Laser In-situ Scattering and Transmissometry

- Mercury

- Organic compounds
  - Polycyclic Aromatic Hydrocarbons (PAHs)
  - Polychlorinated Biphenyls (PCB Congeners)

A large fraction of the metals and non-polar organic compounds in stormwater discharges is adsorbed to solids, especially those small particulates whose high surface-to-volume ratios provide reactive sites for partitioning (Sansalone and Buchberger, 1997; Krein and Schorer, 2000; Shinya et al., 2000; Furumai et al., 2002; Stenstrom and Kayhanian, 2005). These contaminants can cause receiving water quality degradation and toxicity and can pose significant health risks.[2] As such, they cause great concern and are common targets of stormwater particulate monitoring.

Table 3. Physical and Chemical Analyses.

Analysis	Performance Testing	Method Comparison					Summary		
Technique:	Hamlin Prototype	Hamlin Proto-type	Whole Water Centrifuge	Norton Bottle Trap	Fuller Trap	Bottom Sed. Grab*	Sum of Field Samples	Sum of QA/QC Samples[1]	Total # of Samples
No of sites:	3 sites	1 site					-	-	-
No of events:	3 storm events	2 storm events					-	-	-
Physical									
Grain Size	6	4 Incl	2	2	2	2	14	0	14
Percent Solids	6	4 Incl	2	2	2	2	14	5	19
TSS	-	-	4	-	-	-	4	0	4
TOC	-	4	2	2	2	2	12	5	17
PSD (LISST)[2]	-	4	2	2	2	2	12	0	12
Chemical									
Metals[3]	-	4	2	2	2	2	12	6	18
Mercury	-	4	2	2	2	2	12	1	13
PAH	-	4	2	2	2	2	12	6	18
PCB Congeners	-	4	2	2	2	2	12	0	12

* Insufficient material is expected for bottom sediments. Manual trap composites across the study timeframe may be run in place of bottom sediment grabs.
Incl: 4 samples for methods comparison are included in the 6 samples from the performance testing. If possible, this testing will be done to minimize storm chasing.
[1] Field quality assurance (QA) analyses are fully discussed in the *Quality Assurance* section; see Table 7.
[2] The LISST laser diffraction instrument will analyze for PSD both in situ and in bench analyses.
[3] Metals analysis includes arsenic, cadmium, chromium, copper, lead, and zinc.

[2] Cadmium, lead, mercury, PAHs, and PCBs are persistent, bioaccumulative toxics (PBTs) that are a hazard for aquatic life and human health (www.ecy.wa.gov/programs/swfa/pbt/). The other metals being analyzed also have toxic properties and can bioaccumulate but are not classed as PBTs.

Sampling Procedures

Before sampling, all equipment will be thoroughly decontaminated in accordance with Puget Sound Estuary Program protocols (PSEP, 1997). Stainless steel equipment and utensils will be cleaned by washing with Liquinox detergent, followed by sequential rinses with tap water, 10% nitric acid, deionized water, and pesticide-grade acetone and hexane. The equipment will then be air-dried and wrapped in aluminum foil. Personnel will wear non-talc nitrile disposable gloves during all sampling and handling activities. They will change gloves often, as appropriate, to prevent contamination. Table 4 shows the requirements for sample containers, preservations, and holding times (MEL, 2008).

Table 4. Sample Containers, Preservations, and Holding Times.

Parameter	Container[1]	Field Preservation	Holding Time
Conventionals			
Grain Size	8 oz plastic	Cool to ≤ 6°C; *DO NOT* freeze or dry	6 months
Percent Solids	2 oz glass	Cool to ≤ 6°C	7 days
TSS	1 L poly bottle	Cool to ≤ 6°C	7 days
TOC	2 oz glass [2]	Cool to ≤ 6°C; may freeze at -18°C	14 days; 6 months frozen
PSD [3]	2 oz glass [2]	Cool to ≤ 6°C; *DO NOT* freeze or dry	2 days
LISST-PSD	Instrument tubing	NA	NA
Total Recoverable Metals			
Arsenic	4 oz glass [2,4,5]	Cool to ≤ 6°C; may freeze at -18°C	6 months; 2 years frozen
Cadmium			
Chromium			
Copper			
Lead			
Zinc			
Mercury	4 oz glass [2,5]	Cool to ≤ 6°C; may freeze at -18°C	28 days
Organic Compounds			
PAHs	8 oz glass [2]	Cool to ≤ 6°C; may freeze at -18°C	14 days to extraction; 1 year frozen
PCB Congeners	8 oz glass [2]	Cool to ≤ 6°C; may freeze at -18°C	1 year

[1] Jars filled ¾ full to assure minimum sample size for collection, except TSS filled completely.
[2] Teflon-lined cap.
[3] Bench analysis of particulate sizes in sediment samples using laser diffraction instrument.
[4] Six metals combined for analysis.
[5] Container cleaned in accordance with OSWER Cleaning Protocol #9240.0-05 (MEL, 2008).

Sediment Collection Methods

The particulate collection capabilities of the various sampling methods vary widely, and in some cases the total mass of solids collected may be insufficient for analysis of all target parameters. The minimum mass necessary will be coordinated with the laboratory. The project manager will seek laboratory advice on the maximum number of analytes that can be analyzed given the amount of sediment collected and then prioritize the analyses that will most benefit the study objectives.

The following sections summarize procedures for collecting and handling particulate samples for the four sampling techniques used in this project.

Flow-through Sediment Traps

The City of Tacoma "Fuller" design and Ecology's "Hamlin" and modified "Norton" sediment sampling devices will be installed near each other within the stormwater conduits. Installation will be done only by qualified personnel having OSHA 8-Hour Confined Space Entry Certification from the City of Tacoma. The Hamlin sampler will be tethered to the manhole ladder by a nylon rope fastened to the sampler bridle (stainless steel cables extending from each corner of the sampler and meeting at a carabiner in the center of the device; see Figure 3). When positioned at the base of the conduit, the nylon rope will be pulled taut. Pertinent field observations will be noted, e.g., pipe diameter, accumulated sediment in the pipe, flow, and the start time recorded.

Initially, deployments will be inspected approximately daily to ensure that the samplers are still in place and are not being overfilled with particulate material. Later deployments may require less frequent checks. At the end of a sampling event, City of Tacoma confined space entry staff will recover the samplers, taking care to keep them level while lifting to the surface. Using stainless steel utensils, staff will empty captured solids into a stainless steel bowl and homogenize. Staff will transfer aliquots to glass sample jars and label with the sample location name, recovery date, and parameters to be analyzed. Sample jars will be placed in coolers on ice for transport to Ecology's Manchester Environmental Laboratory (MEL) and stored at 4°C until analysis.

Sediment Bottle Traps

Sediment bottle trap sampling will be conducted following standard operating procedures outlined by Fuller and Lowe (2009). An overview of the sampling procedures follows below.

Bottle traps will be deployed at the Tacoma site, beyond the influence of tides, where existing mounting brackets have already been installed. Placement of clean Teflon sample bottles in each trap will require personnel to enter confined space of stormwater conveyance structures. At deployment, site conditions will be documented (e.g., where trap is within the structure, height of trap intake above bottom of structure, whether the trap intake is inundated at all times) and the start time recorded. Two traps will be deployed at a sampling location to facilitate both methods sampling during a storm event and the full duration needed for the bottle to accumulate enough mass of solids available for chemical analyses.

Bottle traps will be retrieved during dry or baseflow conditions between storms both for the methods comparison study and when deployment period ends, at approximately three months. Each bottle will be capped, removed from its mounting bracket, labeled with a sample tag noting the location name and recovery date, and placed in a cooler on ice for transport. Samples will be stored at Ecology Headquarters in a walk-in cooler at 4°C, and disturbances minimized to allow solids to settle. Within 24 hours a portion of the overlying water will be decanted, and the remaining slurry will be centrifuged (1000 rpm for 10-20 minutes) to isolate the particulate fraction. All solids from a single location will be composited and homogenized in a stainless steel bowl, and then transferred to pre-cleaned jars for chemical analyses. Sample jars will be placed in coolers on ice for transport to MEL and stored at 4°C until analysis.

Chemistry data from historical sediment bottle trap sampling by Ecology and by the City of Tacoma will supplement the chemical results obtained for the present study.

Centrifugation

Coincident with a deployment of the prototype sampler on one occasion, continuous-flow centrifugation will be conducted to collect stormwater particulates. A summary of the method is presented below. For additional details see Seiders (1990), Yake (1993), and Gries and Sloan (2008 and 2009).

A peristaltic pump will be used to draw stormwater from the conduit where the prototype sampler is deployed. The pump tubing intake will be attached to the side of the sampler, approximately even with the leading edge (2 to 4 inches above the pipe bottom). Stormwater will be pumped to two centrifuges (Alfa-Laval Sedisamp II, Model 101L) in which particulates will be separated and concentrated. Flow rate to the centrifuges will be measured periodically by determining the time required to fill a calibrated container with centrifuge effluent water. The efficiency of particulate retention by the centrifuges will be monitored by periodically collecting water samples (for TSS analysis) from the centrifuges' influent and effluent tubing at nearly the same time. Centrifugation will proceed for 16 to 20 hours.

After pumping and centrifugation stop, the bowl water from each centrifuge will be removed with a glass syringe and retained in half-gallon glass jars. Solids will be removed from the centrifuge bowls, disks, and distributors with stainless steel utensils and placed in glass sample jars. The bowl water and solids jars will be labeled, placed in a cooler on ice, and transported to Ecology Headquarters. Solids will be removed from the bowl water by centrifugation (2000 rpm for 10-20 minutes) and composited in a stainless steel bowl with the material already in jars. The combined solids will be homogenized to uniform color and consistency, and subsamples will be distributed to pre-cleaned glass jars and sent to MEL for storage and chemical analyses.

Bottom Sediments

At the end of the sediment bottle trap deployment period, an attempt will be made to collect bottom deposits at or near the sampling site. Depending on the configuration of the stormwater conveyance system, material may not accumulate and be retained at the designated sampling location. If no solids are present, efforts will be made to collect the sample from an alternate location further along the system (but before any lateral inputs).

Bottom sediments will be collected as grabs using either a stainless steel scoop at the end of a pole (Cubbage, 1994) or a petite ponar sampler (Wilson and Norton, 1996). To obtain sufficient mass for analyses and to enhance the representativeness of the material, several grabs will be composited at each site. Solids will be homogenized in a stainless steel bowl using stainless steel utensils, and subsamples will be transferred to pre-cleaned glass jars and sent to MEL for storage and chemical analyses.

Particulate Size Analysis Using the LISST Instrument

A laser diffraction instrument (LISST-Streamside, Sequoia Scientific, Inc.) will be used to measure the PSD of in-situ stormwater flows and of captured solids samples. The LISST can detect particulates from 2.5 to 500 um in diameter. During operation, sample water containing suspended particulates is pumped through the instrument, and the measured particulate diameters are categorized into 32 size classes.

Calibrated to certified soil standards composed of natural particles, the LISST uses algorithms to compute the *volume concentration* (uL/L) of each size class – that is, the volume occupied by the solids of a specific size class (uL) per unit volume of sample water (L). The sum of the volume concentrations across all size classes is the total volume of solids (uL) in a unit volume of sample water (L). By dividing each size class's volume concentration by the total volume concentration, the *percent volume concentration* for each size class can be calculated[3]. These values can be used to develop a *volumetric size distribution* for the sample (herein called *LISST PSD*), which describes the fraction of the total volume of solids that each distinct size class contributes[4].

Additional information about the features and design specifications of the LISST instrument is available from Sequoia Scientific's website (www.sequoiasci.com/products/Particle.aspx). The LISST accuracy will be measured against standard materials before each use.

[3] The sum of the *percent volume concentrations* across all size classes equals 100%.

[4] The LISST instrument will produce a *volumetric size distribution*. The traditional grain size analysis will result in a distribution of particle sizes consistent with the PSEP, 1986 protocols. In this document the *particle size distribution (PSD)* will be used to indicate the grain size distribution, and LISST PSD will be used to indicate the volumetric size distribution. The term *PSD* should not be confused with (nor are they directly comparable to) the *mass size distribution*, which results from a grain size analysis.

In-situ Analysis

The LISST will be operated at the two Tacoma sites during the method comparison component of this project. Stormwater will be drawn from the conveyance system to the LISST with a peristaltic or impellor-type pump at regular intervals for the duration of sampling. The location of the LISST pump intake will be proximal to the centrifuge intake and entrance to the prototype sampler.

Snapshots of the instantaneous LISST PSD of the particulates being transported by the stormwater will provide information about whether and how the PSD changes as the sampling event progresses. They will also allow characterization of the "average" LISST PSD of the stormwater for the event. Gries and Sloan (2009) used the LISST in a similar capacity, periodically measuring the LISST PSD in river water to detect temporal variability.

Bench Analysis

A small subsample of the homogenized solids collected by each of the sampling techniques will be analyzed with the LISST to determine the LISST PSD of the captured particulates. Comparison of these bench-measured LISST PSD results to the "average" measured in situ will allow evaluation of how well each technique captures the full range of in-situ particulate sizes, clarifying potential biases inherent to each technique.

When samples are homogenized and distributed to jars for chemical analyses, a subsample for LISST analysis will be reserved in a 2-ounce glass jar. The jar will be filled completely to ensure that the subsample volumes from the various sampling methods are approximately equal. Subsamples will be stored at 4°C for no more than 48 hours and brought to room temperature before LISST analysis.

For the bench LISST PSD analysis, a known amount of each subsample will be diluted in 1 L of deionized water and mixed gently with a magnetic stir bar for one minute. Stir speed will be adjusted to maintain all solids in suspension, but will not be so high as to damage or modify particulates. Water and suspended particulates will be drawn from this well-mixed sample, pumped through the LISST, and returned to the sample. Recycling of the sample through the LISST will continue for several minutes until measurements stabilize.

Laboratory Measurement Procedures

Table 5 presents laboratory analytical methods and reporting limits for the samples collected by the various sampling techniques. These reporting limits will be sufficient for the purposes of this study. All sediment samples will require drying prior to analysis. The percent of air-dried solids in each sample will be used to calculate and report contaminant levels on a dry weight (dw) basis.

Table 5. Laboratory Reporting Limits and Analytical Methods.

Analysis	Matrix	Reporting Limits	Analytical Method	Method Description	Holding Time
Conventionals					
TSS	Water	1 mg/L	SM 2540D	Dry @ 104°C	7 days
Percent Solids	Sediment	1.0 %	SM 2540G EPA 160.3	Dry @ 104°C	7 days; 6 months if frozen
Grain Size [1]	Sediment	0.1%	PSEP, 1986	Wet sieve and pipette (14 size classes)	28 days
TOC	Sediment	0.1 %	PSEP, 1997 EPA 415.1	Acid digest and combustion @ 900°C	14 days; 6 months if frozen
Total Recoverable Metals					
Arsenic	Sediment	0.1 mg/Kg dw	EPA 200.8	ICP/MS	6 months
Cadmium	Sediment	0.01 mg/Kg dw			
Chromium	Sediment	0.5 mg/Kg dw			
Copper	Sediment	0.1 mg/Kg dw			
Lead	Sediment	0.1 mg/Kg dw			
Zinc	Sediment	5.0 mg/Kg dw			
Mercury	Sediment	0.005 mg/Kg dw	EPA 245.5	CVAA	28 days
Organic Compounds [2,3]					
PAHs	Sediment	12 ug/Kg dry	EPA 8270	GC/MS	14 days; 6 months if frozen
PCB Congeners	Sediment	20-50 ng/Kg dry	EPA 1668A	GC/HRMS	1 year

CVAA: Cold Vapor Atomic Absorption.
Dw: dry weight; reporting limit may vary slightly depending on dilutions.
GC: Gas Chromatography; HRMS: High Resolution Mass Spectrometry; ICP: Inductively Coupled Plasma.
MS: Mass Spectrometry.
[1] Results are "apparent" grain size (organic material not removed).
[2] Reporting limits of results will vary for different organic analytes (PAH compounds and PCB congeners).
[3] Complete analyte lists of PAH compounds and PCB congeners can be found in Appendix A.

Quality Objectives

Quality objectives for this project are to obtain data of sufficient quality that uncertainties are minimized, yielding results that are comparable between the various sampling methods and to similar data from other studies. The different pieces of equipment will likely collect different size fractions or types of suspended solids. However, each analytical result will be assessed for comparability and usability. These objectives will be achieved through careful attention to the sampling, measurement, and quality control (QC) procedures described in this plan.

Data quality will be assessed using measurement quality objectives (MQOs). MQOs are performance criteria that delimit the allowable level of error for laboratory analyses. MEL and their contractors are expected to meet the MQOs of analytical methods selected for the project, as outlined in Table 6.

Table 6. Measurement Quality Objectives for Laboratory Analyses.

Parameter	Laboratory Control Samples (% Recovery)	Laboratory Duplicates (RPD)	Matrix Spikes (% Recovery)	Matrix Spike Duplicates (RPD)	Surrogate Recoveries (% Recovery)
Conventionals					
Percent Solids	80 - 120%	≤20%	NA	NA	NA
Grain Size	NA	≤20% [1]	NA	NA	NA
TOC	80 - 120%	≤20%	NA	NA	NA
Total Recoverable Metals					
Arsenic	85 - 115%	NA	75 - 125%	20%	NA
Cadmium	85 - 115%	NA	75 - 125%	20%	NA
Chromium	85 - 115%	NA	75 - 125%	20%	NA
Copper	85 - 115%	NA	75 - 125%	20%	NA
Lead	85 - 115%	NA	75 - 125%	20%	NA
Zinc	85 - 115%	NA	75 - 125%	20%	NA
Mercury	80 - 120%	NA	75 - 125%	20%	NA
Organic Compounds					
PAHs	40 - 140%	NA	40 - 140%	40%	20 - 200% [2]
PCB Congeners	25 - 150%	NA	NA	NA	25 - 150% [3]

NA: Not applicable.
RPD: Relative percent difference.
[1] Triplicate QC samples; MQO given for the relative standard deviation of the triplicates.
[2] Surrogate recoveries are compound-specific.
[3] Labeled congeners; surrogate recoveries are congener-specific.

Quality Control Procedures

Field

Field duplicates allow for evaluation of the variability associated with sample homogenization and allocation procedures in the field. If enough sample material is available, field duplicates will be obtained for each of the collection techniques employed during methods comparison sampling for percent solids, TOC, metals, and PAHs (Table 7). Field duplicates for sediments will be collected by filling a duplicate jar from the parent homogenized sample.

Table 7. Anticipated Analyses of Field Duplicate Samples for Quality Assurance.

Parameter	Hamlin Prototype	Norton Bottle Traps	Fuller Sediment Trap	Centrifuge	Bottom Sediment Grabs
Percent Solids	1	1	1	1	1
TOC	1	1	1	1	1
Metals *	1	1	1	1	1
PAHs	1	1	1	1	1

* Metals analysis includes arsenic, cadmium, chromium, copper, lead, mercury, and zinc.

The manufacturer calibrated the laser diffraction instrument before sale. The LISST will be compared, before and after sampling, to a background sample (deionized water) and two standard reference materials: (1) National Institute of Standards & Technology Standard Reference Material number 1004b – spherical glass beads ranging from 40um to 150um; and (2) Arizona Test Dust standard from Powder Technology Inc., ranging from 0 to 125um and 100-500um. Advisory acceptance criteria for instrument use will be developed using data from these analyses.

Because the Norton bottle trap is expected to have very little sediment accumulated with each storm event, a manual composite of collected sediments from each storm will be considered as the single sample from the entire project. Extra aliquots from the Hamlin and Fuller traps will be stored from each storm to create a full project term composite sample base if enough sediment allows. The composites will be based on total sediment mass normalized and compared to the Norton bottle trap that will be deployed the entire project term. These extra samples will be processed given budget allowance.

Laboratory

Laboratory QC samples to be used in assessing the precision and bias of data obtained in this study are shown in Table 8. To limit QC costs, samples will be held between the sampling events to encourage larger batch sizes, but holding times will not be exceeded. The QC procedures routinely followed by MEL or required of its contractors will be satisfactory for the purposes of this project. QC procedures include blanks, control samples, laboratory duplicates, matrix spikes, and surrogate spikes. The latter three will be run only if sufficient material is available.

Table 8. Laboratory Quality Control Samples.

Parameter	Method Blanks	LCS	Laboratory Duplicates	MS/MSD[1]	Surrogate Spikes [2]
Percent Solids	1/batch	1/batch	1/batch	NA	NA
Grain Size	NA	NA	3/batch	NA	NA
TOC	1/batch	1/batch	1/batch	NA	NA
Metals[3]	1/batch	1/batch	NA	1/batch	NA
Mercury	1/batch	1/batch	NA	1/batch	NA
PAHs	1/batch	1/batch	NA	1/batch	All samples
PCB Congeners	1/batch	1/batch	NA	NA	All samples

LCS: Laboratory control samples.
MS/MSD: Matrix spikes / matrix spike duplicate.
NA: Not applicable.
[1] Extra sample must be provided for MS/MSD samples to occur.
[2] Labeled compounds or congeners.
[3] Metals analysis includes arsenic, cadmium, chromium, copper, lead, and zinc.

Laboratory control samples contain known amounts of analytes and indicate bias due to matrix effects, calibration, and/or sample preparation. Results of duplicate samples provide estimates of analytical precision. Matrix spikes may reveal bias due to matrix effects and provide an estimate of the precision of the results. Accuracy is assessed using standard reference materials.

The organic compound analyses involve spiking each sample with labeled compounds or congeners (PAHs and PCBs, respectively). The concentration of target compounds is corrected for recovery of the labeled compounds or congeners; the remaining compounds or congeners are determined by an internal quantitation technique.

Laboratory Cost Estimate

The estimated analytical cost for the project is $19,946. This includes a 50% cost discount for analyses conducted at MEL. Also included is a 25% surcharge for MEL's contracting services and data quality review for results from contract laboratories.

Table 9. Cost of Sample Analyses.

Analysis	Lab	Number of Samples	Field QA Samples	Lab QC Samples [2]	Cost per Sample [3]	Cost Subtotals
Grain Size	Sub-contract	14	0	0	$95	$1,330
Percent Solids	MEL	14	5	0	$11	$209
TSS	MEL	4	0	0	$11	$44
TOC	MEL	12	5	0	$44	$748
Metals [1]	MEL	12	5	1	$131	$2,358
Mercury	MEL	12	0	1	$50	$650
PAHs	MEL	12	5	1	$327	$5,886
PCB Congeners	Sub-contract	12	0	0	$684	$8,208
					Subtotal:	$17,894
					Contracting [4]:	$2,052
					Total Cost:	$19,946

[1] Metals analysis includes arsenic, cadmium, chromium, copper, lead, and zinc.
[2] With the exception of matrix spikes / matrix spike duplicates (MS/MSD), laboratory QC samples are included in the cost of each analysis. Each MS/MSD is charged the per sample cost.
[3] Unit costs include a 50% discount for analyses conducted at MEL.
[4] PCB Congeners is a contracted analysis for which MEL charges a 25% surcharge. Contracting for grain size analyses will be handled by the project manager and will not incur additional charges.

Data Management Procedures

All field data and observations will be recorded in notebooks on waterproof paper. Relevant information will be transferred to Excel spreadsheets and reviewed for accuracy.

MEL and the contract laboratories will compile analytical results in printed and electronic LIMS[5] formats. The lab data packages will include chain of custody forms, case narratives discussing any problems with the analyses, corrective actions taken, changes to the referenced methods, and an explanation of data qualifiers. All laboratory QC results associated with the data will also be provided in the data packages, including results for blanks, control samples, duplicates, matrix spikes, and surrogate recoveries. This information will be used to evaluate data quality and to determine whether the MQOs were met.

Electronic data from the analytical laboratories will be downloaded from LIMS and analyzed. The project manager will review, analyze, and summarize data during the course of the project.

The EIM data engineer will upload project data to Ecology's EIM database after all data have been reviewed for quality assurance (QA) and finalized.

Data Verification

Field QA procedures will involve reviewing field notes for completeness, errors, and consistency. Duplicate measurements and documentation of conditions in field notes will support verification of field measurements.

MEL will verify that all analytical methods and protocols specified in this QA Project Plan were followed; that all calibrations, checks on QC, and intermediate calculations were performed for all samples; and that the data are consistent, correct, and complete, with no errors or omissions (MEL, 2008). Evaluation criteria will include the acceptability of instrument calibration, procedural blanks, check standards, recovery and precision data, and the appropriateness of assigned data qualifiers. MEL will prepare a written case narrative describing the results of their data review.

The project manager will review the laboratory data packages and case narratives to determine if analytical MQOs have been met. Based on these assessments, the data will either be accepted, accepted with appropriate qualifications, or rejected and re-analysis considered.

After the field and laboratory data have been reviewed and verified by the project manager, they will be uploaded to Ecology's EIM database. Ten percent of the project data prepared for EIM will be independently reviewed for errors. If significant data entry errors are discovered, a more intensive review will be undertaken before finalizing and loading the project in EIM.

[5] Laboratory Information Management System

Data Quality (Usability) Assessment

The project manager will determine if the data are of sufficient quality to meet study objectives by checking for compliance with project MQOs. The final report will discuss data quality, any usability limitations, and whether the project objectives were met.

Audits and Reports

MEL participates in performance and system audits of their routine procedures. Reported results of these audits are available on request.

A draft report of the study findings is expected in April 2012. The project manager will solicit comments on the draft report from the client. This draft will also undergo peer review by Ecology staff who have appropriate expertise and who are not directly involved with this project. The project manager expects to complete the final technical report in July 2012. The report will include the following elements:

- Description of the study design, including field and laboratory methods.
- Maps and photographs of the study areas.
- Pertinent field notes.
- All chemistry data.
- Discussion of data quality and any limitations.
- Summary tables and graphical displays of the chemical data.
- Discussion of significant findings relative to project objectives:
  - Capabilities of the prototype sampler in terms of performance metrics (mass collected, sampling duration, grain size).
  - Comparison of prototype sampler performance and results to other sampling techniques.
  - General assessment of the viability of the prototype sampler for stormwater monitoring applications.
- Recommendations for further action (e.g., design modifications, additional testing).

Upon study completion, all project data will be entered into Ecology's EIM database. Public access to electronic data and the final report for the study will be available on Ecology's Internet homepage (www.ecy.wa.gov).

References

Barnard, B. and C. Wilson, 1995. Stormwater Sediment Trap Literature Review and Design Consideration. Washington State Department of Ecology, Olympia, WA. Publication No. 95-309. www.ecy.wa.gov/biblio/95309.html.

Cubbage, J., 1994. Drainage Basin Tracing Study: Phase II, Chemicals Found in Storm Drains, Whatcom Creek and Squalicum Harbor in Bellingham, WA. Washington State Department of Ecology, Olympia, WA. Publication No. 94-90. www.ecy.wa.gov/biblio/9490.html.

Fuller, R. personal communication, 2011.

Fuller, R. and J. Lowe, 2009. Standard Operating Procedure for Collection of Stormwater Sediments Using In-Line Sediment Traps, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number ECY003. www.ecy.wa.gov/programs/eap/quality.html.

Furumai, H., H. Balmer, and M. Boller, 2002. Dynamic Behavior of Suspended Pollutants and Particle Size Distribution in Highway Runoff. Water Science and Technology. 46(11-12): 413-418.

Gardner, W.D., 1980a. Sediment Trap Dynamics and Calibration: A Laboratory Evaluation. Journal of Marine Research. 38(1): 17-39.

Gardner, W.D., 1980b. Field Assessment of Sediment Traps. Journal of Marine Research. 38(1): 41-52.

Gries, T. and J. Sloan, 2008. Quality Assurance Project Plan: Loading of Contaminants to the Lower Duwamish Waterway from Suspended Sediments in the Green River. Washington State Department of Ecology, Olympia, WA. Publication No. 08-03-114. www.ecy.wa.gov/biblio/0803114.html.

Gries, T. and J. Sloan, 2009. Contaminant Loading to the Lower Duwamish Waterway from Suspended Sediment in the Green River. Washington State Department of Ecology, Olympia, WA. Publication No. 09-03-028. www.ecy.wa.gov/biblio/0903028.html.

Hamlin, T., 2010. Unpublished Data: Grain Size Analysis Results for Prototype Sampler Field Trials, October 2009 and May 2010.

Krein, A. and M. Schorer, 2000. Road Runoff Pollution by Polycyclic Aromatic Hydrocarbons and its Contribution to River Sediments. Water Research. 34(16): 4110-4115.

MEL, 2008. Manchester Environmental Laboratory Lab Users Manual, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Norton, D., 1997. Stormwater Sediment Trap Monitoring of Discharges to Thea Foss Waterway. Washington State Department of Ecology, Olympia, WA. Publication No. 97-322. www.ecy.wa.gov/biblio/97322.html.

Norton, D., 1998. 1998 Sediment Trap Monitoring of Suspended Particulates in Stormwater Discharges to Thea Foss Waterway. Washington State Department of Ecology, Olympia, WA. Publication No. 98-336. www.ecy.wa.gov/biblio/98336.html.

Puget Sound Estuary Program (PSEP), 1986. Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound. Final Report. Prepared for U.S. Environmental Protection Agency, Seattle, WA.

Puget Sound Estuary Program (PSEP), 1997. Recommended Guidelines for Measuring Organic Compounds in Puget Sound Water, Sediment, and Tissue Samples. Final Report. Prepared for U.S. Environmental Protection Agency, Seattle, WA.

Sansalone, J.J. and S.G. Buchberger, 1997. Characterization of Solid and Metal Element Distributions in Urban Highway Stormwater. Water Science and Technology. 36(8-9): 155-160.

Seiders, K., 1990. Particulate Sampling System Operations Guide. Environmental Assessment Program, Washington State Department of Ecology, Olympia, WA. Unpublished Draft Document. 30 pages + Appendices.

Shinya, M., T. Tsuchinaga, M. Kitano, Y. Yamada, and M. Ishikawa, 2000. Characterization of Heavy Metals and Polycyclic Aromatic Hydrocarbons in Urban Highway Runoff. Water Science and Technology. 42(7-8): 201-208.

Stenstrom, M.K. and M. Kayhanian, 2005. First Flush Phenomenon Characterization. California Department of Transportation, Sacramento, CA. Publication No. CTSW-RT-05-73-02.6. www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-05-073-02-6_First_Flush_Final_9-30-05.pdf.

Wilson, C. and D. Norton, 1996. Stormwater Sediment Trap Pilot Study. Washington State Department of Ecology, Olympia, WA. Publication No. 96-347. www.ecy.wa.gov/biblio/96347.html.

Yake, B., 1993. Evaluation of Effluent Centrifugation: Lessons Learned. Washington State Department of Ecology, Olympia, WA. Publication No. 93-e62. www.ecy.wa.gov/biblio/93e62.html.

Appendices

Appendix A. PAH Compounds and PCB Congeners

List of compounds for PAH analysis by EPA Method 8270 Standard Analysis (MEL, 2008).

1-Methylnaphthalene
2-Chloronaphthalene
2-Methylnaphthalene
Acenaphthene
Acenaphthylene
Anthracene
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Carbazole
Chrysene
Dibenzo(a,h)anthracene
Dibenzofuran
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Naphthalene
Perylene
Phenanthrene
Phenanthrene, 3,6-dimethyl
Pyrene
Retene

List of congeners for PCB analysis by EPA Method 1668A. Co-eluting congeners are separated by a forward slash.

PCB-001
PCB-002
PCB-003
PCB-004
PCB-005/008
PCB-006
PCB-007
PCB-009
PCB-010
PCB-011
PCB-012/013
PCB-014
PCB-015
PCB-016
PCB-017
PCB-018
PCB-019
PCB-020/033
PCB-021
PCB-022
PCB-023
PCB-024
PCB-025
PCB-026
PCB-027
PCB-028
PCB-029
PCB-030
PCB-031
PCB-032
PCB-034
PCB-035
PCB-036
PCB-037
PCB-038
PCB-039
PCB-040
PCB-041
PCB-042
PCB-043/049
PCB-044
PCB-045
PCB-046
PCB-047/048
PCB-050
PCB-051
PCB-052/069
PCB-053
PCB-054
PCB-055
PCB-056
PCB-057
PCB-058
PCB-059
PCB-060
PCB-061
PCB-062
PCB-063
PCB-064/072
PCB-065/075
PCB-066
PCB-067
PCB-068
PCB-070
PCB-071
PCB-073
PCB-074
PCB-076
PCB-077
PCB-078
PCB-079
PCB-080
PCB-081
PCB-082
PCB-083
PCB-084
PCB-085
PCB-086/095/098/102
PCB-087/115
PCB-088
PCB-089
PCB-090
PCB-091
PCB-092
PCB-093/095/098/102
PCB-094
PCB-096
PCB-099
PCB-100
PCB-101
PCB-103
PCB-104
PCB-105
PCB-106
PCB-107/108
PCB-109
PCB-110
PCB-111
PCB-112/119
PCB-113
PCB-114
PCB-116/125
PCB-118
PCB-120
PCB-121
PCB-122
PCB-123
PCB-124
PCB-126
PCB-127
PCB-128
PCB-129
PCB-130
PCB-131
PCB-132
PCB-133
PCB-134
PCB-135
PCB-136
PCB-137
PCB-138
PCB-139/149
PCB-140
PCB-141
PCB-142
PCB-143
PCB-144
PCB-145
PCB-146
PCB-147
PCB-148
PCB-150
PCB-151
PCB-152
PCB-153
PCB-154
PCB-155
PCB-156
PCB-157
PCB-158
PCB-159
PCB-160
PCB-161
PCB-162
PCB-163/164
PCB-165
PCB-166
PCB-167
PCB-168
PCB-169
PCB-170
PCB-171
PCB-172
PCB-173
PCB-174
PCB-175
PCB-176
PCB-177
PCB-178
PCB-179
PCB-180
PCB-181
PCB-182/187
PCB-183
PCB-184
PCB-185
PCB-186
PCB-188
PCB-189
PCB-190
PCB-191
PCB-192
PCB-193
PCB-194
PCB-195
PCB-196
PCB-197
PCB-198
PCB-199
PCB-200
PCB-201
PCB-202
PCB-203
PCB-204
PCB-205
PCB-206
PCB-207
PCB-208
PCB-209

Appendix B. Glossary, Acronyms, and Abbreviations

Glossary

Best management practices (BMPs): The specific practices and physical structures used on a construction site to prevent pollution of stormwater.

Congeners: In chemistry, congeners are related chemicals. For example, PCBs are a group of 209 related chemicals that are called congeners.

Conventionals: Non-toxic pollutants.

Conveyance system: A single pipe or series of pipes that convey stormwater as part of a municipal separate storm sewer drainage system.

Dry weather: Less than or equal to 0.02 inches of rain in the previous 24 hours.

First flush: The discharge of a larger mass or higher concentration in the earlier part of a storm relative to the later part of the storm. The term can be applied to any contaminant.

Mounting bracket or ring: A mechanical device used to hold sampling equipment inside a pipe which is pressed against the inside of the pipe for mounting of the sampling device.

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

Particulate: Solid matter, such as a grain of fine sand, small enough to be suspended in a gas or liquid.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Receiving waters: Waters that are subject to pollution discharge**.**

Sediment: Solid fragmented material (soil and organic matter) that is transported and deposited by water and covered with water (example, river or lake bottom).

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead flows via overland flow, interflow, channels, or pipes into a defined surface water channel or a constructed infiltration facility. During rainfall or snowmelt sources of stormwater runoff may include paved and gravel roads, parking lots, roofs, and hard or saturated grass surfaces such as lawns, pastures, and playfields.

Surrogate: For environmental chemistry, a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for QC purposes, to track extraction efficiency, and/or measure analyte recovery.

Total suspended solids (TSS): Portion of solids retained by a filter.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Acronyms and Abbreviations

BMP	(See Glossary above)
e.g.	For example
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
i.e.	In other words
LISST	Laser diffraction particle size analyzer (Sequoia Scientific, Inc.)
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyls
PSD	Particulate size distribution
QA	Quality assurance
QC	Quality control
TOC	Total organic carbon
TSS	(See Glossary above)

Units of Measurement

°C	degrees centigrade
dw	dry weight
ft	feet
g	gram
kg	kilogram
m	meter
mg	milligram
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mm	millimeter
ng/Kg	nanograms per kilogram (parts per trillion)
oz	ounce
ug/g	micrograms per gram (parts per million)
ug/Kg	micrograms per kilogram (parts per billion)
ug/L	micrograms per liter (parts per billion)
uL/L	microliter per liter (parts per million)
um	micrometer
ww	wet weight